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ABSTRACT

An increase in the amount of material to be learned increases the difficulty of the learning task. The function describing this length difficulty relation was obtained by measuring the amount of time 20 college students spent studying arrays of four, six, eight, and ten consonants before they were ready to be tested on them. Identification and location tests were used. For the identification task the length difficulty relation was linear while for the location task a power function with an exponent of 2.39 described the relation. The difference between recognition and recall is qualitative. Students can be expected to assimilate large quantities of information for recognition, while recall requires slower and more careful presentation. Just what is required for a careful presentation remains a problem for future research. (Author)

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# THE REGISTRATION OF INFORMATION IN MEMORY

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March 1970

U.S. Department of
Health, Education, and Welfare

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# The Registration of Information in Memory

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HEALTH, EDUCATION, AND WELFARE

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## SUMMARY

An increase in the amount of material to be learned increases the difficulty of the learning task. The function that describes this length-difficulty relation was obtained by measuring the amount of time people spent studying arrays of four, six, eight, or ten consonants before they were ready to be tested on them. Two kinds of tests were used, identification and location. The identification task required the subject to recognize a consonant presented after the studied array as having been present or absent in the array. The location task also required the subject to recall where the item had been in the array.

For the identification task the length-difficulty relation was linear while for the location task a power function with an exponent of 2.39 described the relation. Apparently the difference between recognition and recall is qualitative. Students can be expected to assimilate large quantities of information for recognition, while recall requires a slower and more careful presentation. Just what is required for a "careful" presentation remains a problem for future research.

## INTRODUCTION

The analysis of the registration aspect of human information processing requires quantitative data on the rate at which information registration can be carried out. The time devoted to a memory task, for example, indicates not only the relative difficulty of that task, but may also be used to infer the nature of the difficulty.

Two kinds of memory tasks are recognition and recall. Recognition requires simply the ability to state that a particular item has or has not occurred in a particular context. Recall requires the recovery of that item or something of the context in which it occurred. With the requirement of a more complete knowledge of context comes increased difficulty. The difficulty of recall relative to recognition is well documented (Adams, 1967, pp. 251-257). At least part of this difficulty results from the increase in response alternatives in recall (Davis, Sutherland, & Judd, 1961; Field & Lachman, 1966).

In the present study some aspects of recognition and recall are compared and the number of alternatives held constant. In the recognition, or "identify," condition subjects are required to remember whether or not an item occurred. In a variation of the recall task, or "locate," the subject's task is to indicate where the item occurred in a set of items. Thus the need to locate an item would require additional knowledge of context, even though an equal number of alternatives are being studied.

It is hypothesized that information about presence and, consequently, absence will require less study time than information about location. In other words, individual items are learned faster than the relationships among items. During the recognition stage the subject learns what the material is and recognizes it as familiar at a later time. In the recall stage material is organized and contextual associations are formed for subsequent retrieval from memory (Underwood & Schulz, 1960; Mandler, 1967).

Furthermore, it is predicted that an increase in the amount of material will have a differential effect on the two tasks. For identification each can be acquired independently of each other item. Thus each additional item will result in an equal increment in study time. Thus each additional item will be a linear function of number of items to be registered in immediate memory.

On the other hand, remembering the location of an item will require the retention of the items and the relationships among them. Therefore, the relationships to be learned, and the time to learn them, will increase as a power function of the number of items. Jensen and Rohwer (1965), however, have suggested that location and the retrieval processes dependent on it may be acquired on the basis of a single association, either with a specific location or with a single adjacent item. If this is true then studying to locate will be a linear function of number of items being studied rather than a power function predicted by the organization hypothesis.

Hypotheses similar to these have been proposed and tested before (Thurston, 1930). The tests usually confound study time per item by using sequential presentations. When the item occurs one at a time and with an inter-trial interval, it is difficult to determine just how the total time of acquisition is distributed in the task (Cooper & Pantle, 1967). Such a procedure might lead to a strategy of learning a set number of items on each trial as found by Waugh (1962). In the present task exposure time equals study time and retrieval is minimized.

## METHOD

The Ss were twenty graduate and undergraduate students at the College of William and Mary. They were paid at least $1.00/hr. as well as being rewarded for their performance as described below. A Scientific Prototype controlled the initiation and presentation time of the array to be remembered.

The materials to be studied were linear arrays of four, six, eight, or ten consonants. Memory was tested by a post-array probe consonant (Waught & Norman, 1965). This consonant was in the array on half the trials and absent on half the trials. On the trials that the probe consonants were taken from the array, they were selected to test all positions an equal number of times.

Each array size was tested in a separate experimental session, randomly ordered. There were 48 presentations of four, six, and eight consonants, and 50 presentations of ten. The first 16 presentations of four consonants, 12 of six, 16 of eight, and 10 of ten were counted as warm-up. Thus the probe officially tested each position 4 times for four consonants, 3 times for six consonants, and 2 times for eight and ten consonants.

Ten Ss were required to report whether or not the probe had been in the array. The other ten were required to give its location in the array. The locate group was given a response sheet with positions numbered to correspond with the array positions being tested.

In summary, a trial consisted of S closing a switch to expose the array, studying the array, and opening the switch when ready to respond. With the switch release the array disappeared and, after a .05 sec. delay, the post-array probe appeared for 3 sec. The S reported whether the probe was present or absent in the array if he was in the identify group and reported its position by number if he was in the locate group.

To motivate the S to be both accurate and rapid a reward system that emphasized both factors was used. The total number of correct responses was multiplied by the number of consonants in the arrays and divided by the average study time on correct responses. This value was then multiplied by one cent. For example, if S got 45 correct out of 48 presentations on arrays of eight consonants and averaged 6 sec. study time on those 45, he made 45 x 8/6 = 60 cents. If he was in the locate group this was

awarded as a bonus to the \$1.00 he received for participating. Since the identify group's study times were considerably shorter, however, they received their reward as their total pay unless it was less than \$1.00.

## RESULTS

Table 1 shows percent total errors and the percent error types. Omission (om.), commission (com.), and mislocation (misl.) percentages are calculated from their actual occurrance and their opportunity to score. With the post-array probe technique omissions and commissions can occur only on trials where the probe is either present or absent, respectively. Mislocation can occur, however, only if the probe is correctly identified as present. Consequently the error types do not sum to the total error percentages.

Errors increased with an increase in array size, $F(3,54)=24.55$, $p<.001$. Mislocations represent the greatest error type increase but all error types relfect the general rise in errors with additional consonants to be remembered.

The error distribution by position showed a skew toward the front of the array. For the identify condition, in which only omissions could be scored for position, 58% of the errors were in the first half of the array for four consonants, 74% for six consonants, 70% for eight consonants, and 84% for ten consonants. In the location condition, where all errors could be scored for position, the first half errors represented 50% for four consonants, 68% for six consonants, 64% for eight consonants, and 57% for ten consonants. When Ss are limited in their time to study, errors are skewed to the rear (Derks & Freeman, 1966).

The difference between the total errors as a function of memory task was not significant, $F(1,18)=3.15$, $p>.05$, and the interaction was not significant, $F(3.54)=1.45$, $p>.05$. Consequently differences in study times between the two groups can be interpreted in terms of task difficulty rather than a change in the S accuracy criterion.

The study times for the various conditions are shown in Fig. 1. An examination of the ranges indicated that a logarithmic transformation was most appropriate for minimizing differences between the variances. Such a transformation was also indicated by the a priori prediction of a power function relating study time to array size for the locate group. Therefore the geometric mean study times are given.

Study time to locate was greater than study time to identify, $F(1,18)=34.48$, $p<.001$. The additional recall requirements increased study time even though the number of consonants were equal.

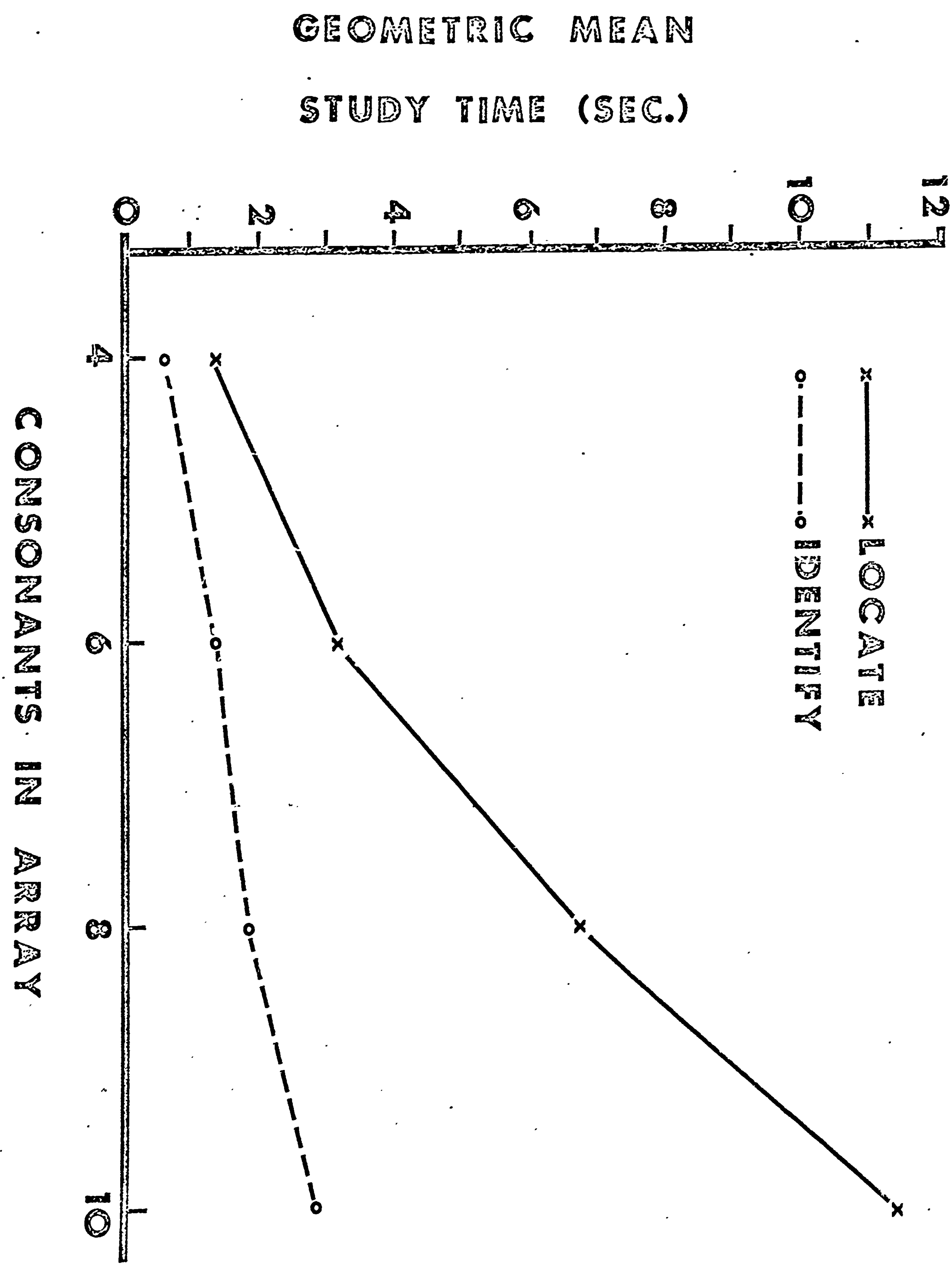
The number of consonants in the array also increased study time, $F(3,54)=128.46$, $p<.001$ and the interaction with the task was also significant, $F(3,54)=5.03$, $p<.005$. As would be expected from visual inspection, the identify curve is more linear than the locate curve. For identification 98.8% of the variance is linear while for locate 96.6% is linear. It should

Table I

Percent Errors

ARRAY SIZE

| COND. | 4 | 6 | 8 | 10 |
|---|---|---|---|---|
| Identify | 6.9 | 12.8 | 15.3 | 20.3 |
| om. | 7.5 | 12.8 | 14.4 | 18.5 |
| com. | 6.3 | 12.8 | 16.3 | 22.0 |
| Locate | 1.3 | 6.1 | 14.7 | 20.3 |
| om. | 0.0 | 1.3 | 8.8 | 9.5 |
| com. | 1.3 | 2.8 | 4.4 | 6.5 |
| misl. | 1.3 | 8.4 | 17.8 | 27.1 |


GEOMETRIC MEAN
STUDY TIME (SEC.)
0
2
4
6
8
10
12
LOCATE
IDENTIFY
4
6
8
10
CONSONANTS IN ARRAY

be noted that power functions generally yield a majority of their variance as linear (Green, 1968). In fact, a curve described by the square of the dependent variable, $x=y^2$, shows 92% of the variance as linear. In any case, a power function $T=0.046\ N^{2.39}$ with T=study time in sec. and N=number of consonants, gives a better least squares fit that a linear function. The $\chi^2$'s between observed and expected points for the two types of functions are 0.70 and 122.16, respectively. Other possible functions will be considered in the discussion.

Study time for the identify condition is fit by least squares with the linear equation $T=-0.85 + 0.36N$. The negative constant suggests that Ss could identify an array of 2.36 consonants in 0 exposure time. Nevertheless, for the empirical points the $\chi^2$ values for a linear function and the best fitting power function are 1.46 and 2.32, respectively. This small difference favors the predicted linear effect of array size on study time to identify but the result is not conclusive.

## DISCUSSION

The original hypotheses concerning relative difficulty of identifying and locating in immediate memory were supported. Furthermore, the identify and locate tasks appear to be qualitatively different on the basis of the functions relating study time to the amount of materials. Stevens and Galanter (1957) have discussed the difference between linear functions and power functions in the context of psychophysical scaling. Their reasoning also seems to have relevance for the present data on immediate memory.

When a change in a physical stimulus (wave length) produces a linear change in the psychological response (color, pitch) the underlying physiological process is a substitutive one. They have termed such a relation metathetic. When the change in the physical stimulus (energy) produces a change that is best described by a ratio, i.e. a power function (brightness, loudness) the underlying physiological process is additive. "The distinction between...(Prothetic) and...(Metathetic) is something like the traditional distinction between sensory intensity and sensory quality, but it is not quite the same." (Stevens & Galanter, 1957, pp. 378).

The extension of this reasoning suggests that the process of studying to identify is a substitutive process. An item is registered without relation to the other items. Studying to locate, on the other hand, is an additive process. Each additional item increases the difficulty of every other item. Perhaps because organizational relationships are formed among all items.

Nevertheless, there are some arguments against this interpretation. First, there are other functions that can fit the relationship between study time to locate and number of items. Although a single linear function does not fit the data, a dual function can fit the four points and has certain theoretical justification. Miller (1956) has argued for a discontinuity in information processing at around seven items. In other words, only material

of over approximately seven items must be organized while less material can be registered directly into immediate memory. This theory, however, would predict a slope of zero for the function relating study time to less than seven items. The subject would study arrays of less than seven items an equal amount of time. Such is not the case. Nevertheless, further data is necessary to decide between the power function and the dual-linear function. In fact, Mackworth (1966) has used two linear functions connected by a log function to fit data on items correct as a function of exposure time.

A second argument against the organization interpretation is the absence of introspective reports of any but very gross, rythmic groupings of items. Mnemonic devices were rare and showed no evidence of either speeding or slowing performance. The Ss felt that the increased time per item with increased material was a result of rehearsing the items more slowly, rather than repeating the array more often prior to test. A direct examination of rehearsal would be valuable in determining more about the nature of registration in immediate memory.

The rythmic rehearsal reported by the Ss suggests an alternative test of the organization hypothesis. If the added time is a result of subjective organization then organization supplied by the material itself should decrease study time. For example, if the material is presented in a form with perceptual structure greater than a linear array, study time should be reduced. In a two-dimensional matrix, for example, the requirement to organize the material with respect to the list as a whole would be minimized and S could use visual cues for structure.

In any case, from the point of view of application to education, the present study indicates a qualitative difference between recognition and recall. The organizational requirements of recall decrease the registration rate of material and further decrease the rate per item with additional material. The recognition task has much less effect on rate and material can be piled up more quickly and with the upper limits greatly extended. Thus, the nature of the task as well as amount of material must be considered when preparing studying and testing strategies. Further research in this area should consider the value of organization short cuts and general techniques for improving organization.

## RECOMMENDATIONS

Basic research reduces a problem to its simplest form. There are two reasons for this reduction. In the first place, a simple situation is easier to study than a complex one. Second, and more important, when a problem is reduced to its elements and the elements are understood, it is possible to generalize back to all complex situations that contain these elements.

If research only examined the "real-life" situations generality would be reduced. Just because two situations have aspects in common does not

mean that the situations are fundamentally the same or that the common aspects are the critical aspects. Analysis leads to generality. A phenomenon understood in the relative simplicity of the experimental situation can be more readily understood and manipulated in the applied situation.

The relationship between task length and acquisition difficulty is a problem that requires analysis. In the classroom, acquisition difficulty is confounded by the experience of the student, the meaningfulness of the material, the student's attention, and so forth. In the present experiment, the experience of the student with lists of random letters was very limited. The letters themselves are well known and independent. The student's attention was more or less held by the monetary reward. The problem has been reduced to its essentials and these essentials were examined against a controlled background.

As indicated in the introduction, several length-difficulty relations may hold and have been reported. The major finding of this study was that for a recognition task the relation is linear and for a recall task it is a power function. What does this mean in the classroom?

The classroom equivalent or "task" is a lesson to be learned. The first decision that the teacher and student must make, and agree on, is the level of learning that will be satisfactory. If the task is essentially recognition (multiple choice, true-false) the requirements can be set as a function of the time available. Material that is to be recognized can be assimilated rapidly and, to some extent, continuously.

If, on the other hand, the requirement is for a deeper kind of memory which includes the ability to recall information, greater caution must be shown. Not only does such learning take longer, but the slope of the power function indicates a practical upper limit to the amount that can be accurately recalled in a single context. In this respect the optimum number of things to be learned is one. Lessons usually make greater demands, however, and more information is required to give meaning to the whole. Nevertheless, whenever possible, the upper limit should be about eight "things" as efficiency deteriorates faster than information builds beyond that point

"Things", of course, are not limited to consonants in an array. The concept should generalize to words, facts, ideas, anything that is unitary in itself. Thus when material is presented, or studied, it should be organized into contexts that contain less than eight elements for learning to be relatively more efficient.

This principle expands to lesson plans, lectures, and textbooks. A further point that may have some value for lectures and textbooks is the distribution of errors in studying. The errors in both recognition and recall occurred primarily in the part of the array probably studied first, even though the subject could have gone back to check before testing. Thus the lecturer and the author would do well to reiterate important material from the beginning of the presentation.

The lecturer and film strip designer has a further duty to the audience in the pacing of this presentation. Material of minor importance, material that will only be recognized, can be presented quite rapidly (3 items per second if need be). Important material, material to be organized and recalled, must be presented slowly and perhaps repeated.

These principles seem to meet in the design of programmed instruction. In general, programs do proceed relatively slowly so that the learner makes few or no mistakes. Material that is elicited by recognition could be speeded up, however, while material to be recalled requires slowing down and repetition, rather than only being retested on errors. The program must discriminate the acquisition requirements, recognition or recall, and present the material accordingly.

The length-difficulty relation is a central question in education. How much can a person learn and how can that capacity be extended? The present study has supplied further data to help answer the question.

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